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van den Bergh, J.C.J.M.; Nijkamp, P.

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A CASE STUDY IN AGRICULTURAL DEVELOPMENT PLANNING IN THE NETHERLANDS

J.C.J.M. van den Bergh

P. Nijkamp

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ECOLOGICALLY SUSTAINABLE ECONOMIC DEVELOPMENT IN A REGIONAL SYSTEM:
A CASE STUDY IN AGRICULTURAL DEVELOPMENT PLANNING IN THE NETHERLANDS*.

Jeroen C.J.M. van den Bergh   Peter Nijkamp

Faculty of Economics
Free University
P.O.Box 7161
1007 MC Amsterdam

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Abstract.

This paper focuses attention on the relevance of the notion of sustainable development in a regional context and the use of models in analyzing sustainable development. The paper discusses first the notion of sustainable development, linking socio-economic, ecological and political-ethical elements. Time and space prove to be important dimensions of sustainable development, in both distributional and tradeoff questions and dynamic growth processes. The concept of sustainable use of resources and its relevance to sustainable development will also be discussed. In that context multiple use and uncertainty are important concepts.

In a spatial context, an often neglected but interesting concept is that of regional sustainable development. Its relationship with both the global concept of sustainable development and sustainable use of resources will be discussed.

In the paper, we will focus on the use of models for sustainable development in general and in a regional context. All such models integrate economy and ecology: a description of economic processes, ecological processes and their interactions; and an inclusion of socio-economic and ecological indicators in the evaluation. Only dynamic models will be considered here, as they are seen to be the most relevant class for tracing sustainable development. It is argued that systems models are most appropriate on a regional level, as here the level of detail of describing economics and ecology (and their interactions), including their policy relevance, is fairly balanced.

Finally, a case study is presented for the Peel region, an agricultural area in the Netherlands, where presently agriculture causes considerable damage to groundwater, forests, and protected fen areas due to intensive cattle farming, irrigation and drainage.

1. Introduction.

The concept of sustainable development (abbreviated as SD) has intensively been discussed at a global level. The aim of this paper is to investigate the relevance of this concept, by focusing attention on the **regional** implications of sustainable development. Hence, in this paper the concept of regional sustainable development (abbreviated as RSD) will be introduced and outlined. In this framework, the attention will be directed towards a discussion of the characteristics of models that can be used to clarify SD and RSD notions, and to trace such developments. First, in the next section, SD is discussed. In section 3 we present a more specific approach to sustainable development on a regional scale. The concept of a regional resource base is discussed and clarified in section 4. The two subsequent sections deal with models for SD and RSD, respectively. Finally a case study for an agricultural area in the Netherlands is presented, that uses simulation techniques for the analysis of RSD.

2. Sustainable Development.

The concept of SD is - particularly since the publication of the Brundtland report (WCED, 1987) - increasingly referred to in integrated economic-ecological analyses. This concept reflects a compromise between the aim of economic growth and concern for the environment. It recognizes the goal of survival of the human species, realization of an acceptable quality of life for each individual in present and future generations, preservation of diversity and quality in the natural environment, and wise management of natural resources and ecosystems (see also Archibugi and Nijkamp, 1989).

'Sustainable' denotes that the necessary conditions for some phenomenon to occur are permanently satisfied. Bearing this in mind, the following definition of ecologically sustainable economic development can be proposed: the development of economic activities, human preferences and human population, such that an acceptable standard of living for every human being is ensured (the phenomenon) and all aspects of this development can be fulfilled in the long run by natural resource availability, ecosystems and life support systems (the necessary conditions). 'Ecologically sustainable' refers to the continued existence of the environment, which acts as a basis for human welfare, as it provides living conditions and environmental amenities and also acts also as a productive basis. The concept of 'acceptable standard of living' calls also for further explanation. Brown et al. (1987) state that all humans should, once born, live to adulthood with a quality of life beyond mere biological survival. Tolba (1987) mentions elements that are essential in arriving at such a quality: food self-reliance, health control, clean water and shelter. While these are especially relevant to developing countries, Pearce et al. (1988) mention additional attributes that are also more relevant to developed countries: real income per capita, education, access to resources, basic freedom and distribution of income.

Although an operational definition of SD is hard to find, one may identify the kind of elements and strategies involved: SD is the development of economic activity which generates sufficient amounts of goods and services for all generations, such that important renewable resources are used uninterruptedly and pollution is kept below a critical level, while important non-renewable resources are used sparingly. Tradeoffs, substitution and extinction are - temporally or locally - allowed for less important resources. Importance of resources refers to uniqueness of special characteristics, the fact that they are essential for fulfilling basic needs or for keeping life support and eco-systems intact. Sustainable use of renewable resources means that the rate of use is not higher than the controlled or natural regeneration rate of the resource. The critical level of pollution is determined by the assimilative capacity of the environment, dispersion patterns, tolerance and thresholds within each hierarchical level of ecosystems, and the requirement of maintaining life support systems and ecosystems that are essential for providing important direct services to man.

Many **global** environmental problems are caused by the total of a great many small-scale and **local** activities. The fact that the level of economic processes is moving towards a global scale, with more interactions between nations, adds to these problems. Moreover, the effects of environmental changes are experienced at the regional level. Also, the allocation of land (land use) is an important determinant of environmental developments. All in all, there seem to be many reasons for considering the regional impacts and implications of SD. In addition, a regional scale allows one to choose reliable and measurable indicators, while also development scenarios and concrete policy objectives and strategies can be identified and analysed much easier. Thus, by focussing on regions, it is in principle possible to operationalize SD.

3. Regional Sustainable Development.

RSD may be regarded as a translation of the global concept of SD to the regional level. However, a region cannot be regarded in isolation from others. And often it is necessary to consider regional development in relation to interactions with other regions and their respective developments. In view of this openness of a spatial system, a different approach is necessary compared to that for a closed global system. One may define RSD as a regional development that fulfils **two conditions:** (1) it should not be in contrast with SD at a supra-regional level; (2) it should ensure at the same time for the regional population an acceptable level of welfare, which can be sustained in the future. The first feature ensures that RSD does not compromise the welfare level of other regions.

In this context a methodological question which is relevant for real-world problems and policy issues is: can a meaningful and operational concept of RSD - and guidelines for policies to obtain RSD - be derived from the global concept of SD? If the answer is affirmative, then RSD should satisfy the following requirements. (1) A single RSD is always compatible with a global SD. (2) If all regions of a global system have a RSD, then the development of the global system will be sustainable.

A **first step** towards RSD analysis is a stock-taking of the characteristics of the internal structure of a region, its interactions with other regions and relevant global phenomena. Based on this information, one may arrive at a more clear view on the potentials and constraints for the region's future development. Examples of such features are the state and structure of the socio-economic system, the nature of the resource base, and the interactions between both. Starting with the present situation, one may then extrapolate the past to determine future states of the regional system.

A **second step** in RSD analysis involves the assessment of both feasible and uncertain developments that deviate from the extrapolated course. Examples of such feasible developments are policy actions, expected technological developments, investment programmes, conservation programmes, and social programmes. Uncertain, and also more drastically changing, developments may relate to the development of new (or the disappearance of old) economic sectors, governmental investment (e.g., in infrastructure), or changes in institutional arrangements. The assessment of future developments relevant to the regional system development should also include extra-regional developments, especially with respect to resource availability, demand for exported goods and services, prices (or competition, substitution products and demand factors) and pollution emissions.

Then a **third step** in RSD analysis is the evaluation of different development paths for the regional system under consideration. In order to do this first a set of performance indicators and an evaluation method have to be designed or identified.

Two types of **indicators** are important in the evaluation of sustainable development of a region. In the first place, indicators should provide the information necessary for the determination of the desirability of a **state of the system at a point in time.** These are indicators of welfare (i.e., for static evaluation), and may include income distribution, regional per capita income, sectoral diversity, unemployment, public services, infrastructure, land use, level of congestion, amount of vegetation, species diversity, water quality, etc.
Secondly, indicators also should provide information about the **potentials and constraints for future development** of the regional system (i.e., for dynamic evaluation). For the latter purpose are - in addition to the indicators already mentioned - especially important indicators based on ratios such as: productivity ratios of resource input to production output, ratios of resource depletion to stocks and renewal rates, ratios of actual to

acceptable pollution levels, rates of change in pollution, stock of pollution, changes in relative uses of land in the region, ratios of imports and exports to regional income, ratios of regional productivity to maximum possible productivity (of factors in production), etc.

In the **evaluation** of the timepaths of indicators one may judge the development on the basis of acceptability of levels and fluctuations (e.g., too strong fluctuations in income levels and unemployment rates may not be acceptable from a social point of view) and highest values attained (in the case of ratios and changes), while for stocks minimum or maximum values attained provide relevant information. In case of multiple indicators it is plausible to use multiple criteria-like techniques for the evaluation of developments with respect to RSD. However, putting weights on specific indicator outcomes is not easy, and important issues such as stability and fluctuations cannot always directly be included. Formulating constraints for ensuring acceptable development paths seems then more useful. This also complies with the fact that RSD as a multi-dimensional concept does not presuppose simple judgement criteria, and will certainly not result from optimizing a uni-dimensional criterion.

In order to provide a more concrete approach to RSD - and of more relevance in an operational context - it is meaningful to introduce the concept of **sustainable resource use**. This applies mainly to renewable stocks of natural resources and reflects the idea that the use of goods and services provided by such stocks can be arranged so as to maintain some optimal stock level. In such a way it is possible to enjoy a certain amount of resource goods and services for a long period of time. RSD may then provide an appropriate bridge between sustainable resource use and SD. Sustainable use of a region's stock of resources may be regarded as an important necessary - though not sufficient - condition for RSD. Such a conservation strategy is a kind of risk-avoiding strategy. If a stock of renewable resources is wisely used, it may generate a flow of materials and/or services for an unlimited period of time. If this flow is sufficient for generating an acceptable welfare level for the regional population ('sustainable welfare'), it is clear that one should aim at a conservation of the resource. Thus resource management is a critical variable, as overexploitation or extinction of a resource is in most cases an irreversible process. Moreover, wise management of the resource guarantees at least that for a long time (part of) regional income is ensured. Furthermore, alternative non-renewable resources should be considered in their specific context according to their own features. For example, other 'resources' which may also be preserved and which may be important elements of welfare, are landscape and various artefacts (e.g., monuments).

If for a given region its RSD is independent of the rest of the world, then it is self-sufficient (i.e., it may be regarded as a closed system). More interesting however are open regions. In the case of an open multiregional system, the final result for RSD depends inter alia on the type and volume of goods and services the region offers the rest of the world. Regional interactions include: imports and exports of resources, intermediate goods, commodities, services, capital and pollution; migration and commuting; and flows of profit, income, and savings. Sometimes the export of services is explicitly based on the availability of a specific geographical feature, e.g. accessibility. Harbours are typical examples of this.

It is possible that SD demands short-term 'sacrifices' to the detriment of current regional development. By 'sacrifice' we mean a reduction in welfare for a part of the population or for a certain period. This may happen, for instance, when certain regions are used for specific environmental or economic purposes (such as conservation of natural areas, concentration of industrial activity, or dumping of waste) or when the climate and other physical conditions put severe constraints on future development (e.g., dry, mountainous and cold areas). Other regions may however develop according to more diverse growth patterns, in which welfare, economic activity and natural environment run parallel. This may evoke the need for analyzing implications of SD, with a particular view on the difficult problems of regional compensation or substitution of welfare.

As RSD probably implies that no unneccessary risks be taken and undesirable states be avoided, a concept like **carrying capacity** may be useful, to denote an upper limit to certain growth patterns in a region. It may refer to the upper asymptote of a logistic (sigmoid) curve, which is often used as a simple description of population growth in ecology (see e.g., Wilen, 1985). When applied to the population of people in a region, carrying capacity indicates the number of people that a region can support. It may be useful in a specific regional context in a various ways, e.g., as an indication of the number of residents or tourists the region can accomodate. Three aspects play a role in the determination of carrying capacity:

- biophysical elements;
- behavioural elements; and
- economic amenities.

The first aspect includes spatial considerations, stress factors related to ecosystems, sensitivity of animal and vegetation species, soil, climate, groundwater and surface water characteristics, etc. In the second category fall density, congestion and crowding which can be related to preferences of population and tourists. The third category includes amongst others supply of goods and services, housing facilities, and employment.

Carrying capacity is a dynamic concept, and may be improved by management of natural environments, so that for instance the biophysical aspects become less constraining. Especially economic amenities can be influenced to improve the carrying capacity.

In view of the above mentioned characteristics, a wide variety of different types of specific regions can be distinguished; developed regions, densely populated areas, urban regions, industrial areas, environmentally protected areas, lagging regions (in many aspects), islands, recreational areas, etc. It is impossible to classify according to specific features of RSD a set of regions in general. Only when the regional characteristics are specified in more detail, it is possible to typify RSD. For this reason research on RSD should partly be devoted to case studies of various types of regions. The specific choice of regional boundaries should be based on the relevant interactions between economic activities and the resource base - which will be dealt with in the next section -, while also taking into account the interactions with other regions and relevant global environmental processes (e.g., the rise of the sea level in the Netherlands).

4. A Resource Base for Regional Welfare.

Regional development is often critically dependent on the regional supply of resources. Some authors have argued that especially regions with energy resources and agriculture will exhibit a strong growth in income levels, as opposed to regions dependent on external energy sources, that have experienced rapid growth in the past because of low energy prices (see e.g. Miernyk, 1982). Many types of regional economic dependence on its resource base can be distinguished:

- the regional economic system is directly dependent on the resources in the region; for instance, resources in the region may serve as essential and cheap **productive inputs** to economic activities, e.g. energy resources; also the quality of the resources may be relevant in order to guarantee a sufficient level of activity for a specific sector, e.g., in agriculture and tourism; moreover, the environmental capacity as a sink of waste materials and pollution can be a restrictive factor to economic activity;
- **export of resources** is a main source of income for the region; in some regions a sharp rise in per capita income levels is clearly caused by such a relationship, e.g., in oil-exporting countries, in tourist areas and in coal mining regions in the U.S. (Miernyk 1982).
- local physical needs are served by **local activities** based on the available regional resources (e.g. agriculture, energy and water utilities and industries using inputs from forests, mineral mines and ore mines);
- regional welfare, as far as not included in the above, depends directly on the resource base (or regional ecosystem, in general), as it generates **amenities**, for instance, to local recreation; and,
- a regional resource sector has many **impacts on other activities** in a region, as a result of an increased demand for public services, utilities and infrastructure, demand for labour, capital and space, and spin-offs to other private sectors; thus the development of a resource sector may generate shifts in sector allocation, income levels and distribution and exchange rates (see e.g., Siebert 1984).

Although we have used in our analysis the concept of a **resource base** in a rather general way, its specific meaning has to be clarified now. We define it here as the complex of resources and their regenerative support systems, in particular for those resources that are critically important for regional welfare, either via regional economic activities or regional physical and non-physical needs satisfaction. We will now briefly describe the resource base for several types of resources. For non-renewable resources (ores, fossil fuels) the resource base may be defined as the resource itself. In case of an abiotic renewable resource (water, soil), the system containing the resource as well as the biotic and abiotic subsystem that affect its regenerative capacity can be considered as the resource base. For biotic renewable resources (population, e.g.) a distinction made by Opschoor (1987) is useful. He distinguishes in the natural environment between an ecosystem, a regenerative system and a resource, the latter two being subsets of the constituent system. The regenerative system supports the existence and regenerative capacity of the renewable resource (according to Opschoor it acts as a "natural supporting plane" of the renewable resource). In the case of a renewable resource the regenerative system can be regarded as the resource base.

After this discussion of the relevance of a resource base for regional welfare, various important questions in the context of SD with respect to its continuity and optimal use deserve attention. Especially six characteristics are interesting in this context, viz. whether

1. the resource can be exhausted;
2. the resource is potentially renewable;
3. the resource is multifunctional;
4. the resource base is stable;
5. the resource base is a closed (natural) system; and
6. the resource is a private or a public good.

Ad 1. If the resource cannot be exhausted in any way, clearly no problem concerning its optimal and indefinite use exists. For most resources however, exhaustion is a realistic option. In these cases it should be analyzed which processes lead to exhaustion, at which rate and with which probability. Uncertainty pertaining to initial resource stock values and stability of the resource base (for renewable resources) imply that risk aversion may be an important element in strategies of resource use.

Ad 2. Resources are classified as renewable if their regeneration rate can occur in human time spans. Renewable resource use can be sustained indefinitely if the rate of use (e.g., extraction, harvesting, pumping) is equal to the rate of regeneration. This rate can be influenced both positively and negatively, by human actions. Of course, uncertainty is also present here, as the nature of regenerative processes is not always well understood and because regeneration is subjected to environmental variability. Non-renewable resources can at best be used prudently, as a strategy of sustainable use is not feasible. Moreover, non-use would imply that they are not critically important for regional welfare, so that they would not form part of the regional resource base anyway.

Ad 3. If a resource fulfils more than one function, conflicts of use may arise. This may pertain to several economic sectors, to productive and amenity services, and to economic and ecological services. An optimal combination of uses attempts to achieve both a stable development of the resource and stable patterns of uses over time. Feasible and optimal multiple use of resources should therefore take into consideration both possible economic and ecological conflicts. For the different functions and uses it should be determined to what extent they are complementary or conflicting. Moreover, one should look for management tools that can reduce the conflicts. If a specific function or use is strictly necessary, one should assess which constraints it puts on other functions and uses. In addition, the concept of multiple use is also relevant in an actual situation of single use, if other potential uses can be identified.

Ad 4. The next feature mentioned, stability, is relevant for resource bases of biotic and abiotic renewable resources. Both the quality and quantity of such resources can vary and it is desirable to induce stable developments concerning these resources. For example, the harvest rates of populations and the extraction of groundwater for drinking purposes must be chosen in such a way that the quantities and qualities do not fluctuate too strongly or collapse. Also with regard to polluting activities the stability concept is relevant, for instance, in deciding which level of pollution is safe in view of the assimilative capacity of certain regenerative systems. Especially for multiple use resources, stability is an interesting feature, as many factors influence it. We have to find out which combinations of different uses generate a stable behaviour of the resource, so that a choice for one of these combinations can be made.

Ad 5. The openness of the resource base is important for the type, intensity and effect of control measures. For instance, a closed resource base within the region can be controlled including its use (e.g., harvesting, pumping, dumping of waste, polluting), maintenance and special treatment (fertilizing, irrigating, cleaning)) without any concern about the influence of external factors. In many cases regional resource bases extend beyond regional borders (for instance, river systems). Control at a supra-regional level would then be necessary.

Ad 6. The distinction between private and public goods resources is relevant, as they imply different types of management rules and governmental action. The first type of resources can be controlled without interference from outside. This applies for instance to soil and coal, iron and mineral mines. The second type includes both common property and open access resources, whose management is far from easy. Examples of common property resources are oil and gas reserves, whilst examples of open access resources are air, groundwater, surface water and fishery. For this second type of resources governmental regulation or taxation, or single management (acknowledging property rights, permits or governmental ownership) may be remedies.

In view of both the great many different types of (potential) uses of a resource base and the characteristics of the resource base, one should identify which uses are relevant in the context of a specific region. Once the potential and present interactions and the character of the resource base have been determined, it makes sense to examine the potentials and constraints that apply to RSD.

5. The Use of Models for Sustainable Development.

An important question regarding the use models for SD is which specific type of models is relevant for gaining insight into SD issues, or for tracing SD paths. This question may be answered by dealing with model structure and specification aspects on the one hand and model use and evaluation aspects on the other hand.

The most significant features of models for SD, distinguishing them from other models used for environmental problems are:

- a module that describes the dynamics of resource bases and ecosystems so that the indirect effects and consequences of specific economic developments for natural environments can be traced;
- feedback of ecological impacts of economic activity to the economic system; in this way the ecosystem provides the economic system with dynamic physical constraints and potentials;
- inclusion of qualitative development and change; this calls for a detailed description of sectoral interactions, and decision and behavioural processes; however, uncertainty about social and technological processes makes it very difficult to include qualitative elements;
- inclusion of production and welfare elements; this means both a modeling of the economic structure and a valuation of production (including also a valuation of welfare derived from the non-productive use of the natural environment); in general, both potential and actual productive and non-productive uses of the environment are to be modelled.

SD is concerned with development over a long period, focussing on stability issues and especially **structural changes**, i.e., changes that result in qualitatively different characteristics of states and/or behaviour of the system under consideration (viz. an integrated economic-ecological system). Clearly, models should in any case be dynamic to serve SD purposes. Some structural changes may be endogenously generated by a model. Mathematical theories of chaos and bifurcation for example have shown that simple dynamic models can generate behaviour with changes in qualitative characteristics of states (see Baumol and Benhabib, 1989; and Nijkamp and Reggiani, 1990). But most structural changes result from forces from outside a model, since they are uncertain in their nature and characteristics. In modeling terminology, structural changes may emerge in the following ways:

- time paths may include non-smooth or discontinuous parts as a result of reaching boundaries imposed by model constraints;
- the parameters of a system of dynamic equations may change and give rise to different qualitative behaviour: e.g., the number and/or character of equilibria may change;
- the functional form of a relationships may change;
- relationships and variables may be deleted from or added to the model at hand; and,
- stochastic specifications may generate time paths with sudden changes in the value of variables; in the case of small disturbances, this also shows a high sensitivity of model behaviour to parameter or initial stock values.

It is however possible to use models in such a manner so as to anticipate various - sometimes less probable - changes, e.g. by combining several scenarios with simulation models. But real uncertainty about processes leading to structural changes and the change in qualitative characteristics in the system means that it is never possible to overcome these problems, as this is essentially a consequence of limited knowledge about real-world processes.

A main advantage of using models in the context of SD is the fact that they can replicate part of the complicated nature of real-world processes. Especially the complicated pattern of interactions within and between economic and ecological processes call for a detailed description. Indirect and feedback, non-linear, time-delayed and other kinds of relationships can be dealt with most appropriately in a formal logical framework. Simulation models are especially suitable for incorporating many theoretically and empirically obtained results of partial studies. In that sense a model provides a means for summarizing many valuable insights, while they can be tested and improved. Moreover, with inclusion of uncertainty in specification and use of models one may obtain quantitative, comparable and more precise estimations than an intuitive reflection on relationships between uncertainty and indicator values (with simulation meta-regression techniques; see Law and Kelton, 1982). Other relationships can be derived in a similar manner. In principle it is also useful to analyse expected or unexpected socio-cultural, institutional and technological changes within a modeling framework. A prerequisite then is that some information on the main effects of such changes upon various elements in the economic-ecological system is available.

The treatment of more detailed requirements and options referring specifically to models for RSD will be pursued in the following section.

6. Models for RSD.

Most dynamic (multi)regional models are either programming, simulation, or analytical models. Programming models optimize either one or more objectives, can solve dynamic problems, and also nonlinear problems, provided they are not too complex. **Simulation models** have the following characteristics:

- a detailed systems description, only restrained by the demand for data;
- a subdivision of the whole model into modules: specific ecosystems, economic sectors, factor markets, decision-making units, population and spatial subdivisions;
- interactions between multiple regions or modules for sub-system descriptions;
- possibility of inclusion of nonlinear, dynamic and stochastic specifications; and,
- possibility of econometric, input-output or stock-flow specifications or combinations of these.

Most modeling approaches use only one single technique. The shortcomings of each one technique can be compensated by using **multiple techniques in a coherent combination.** For instance, Lonergan (1981) proposed to combine the use of a programming model with a simulation model. The simulation model was used in his framework to describe the ecosystem being controlled for economic purposes. An optimizing module was used to include normative aspects (i.e., maximizing total added value of regional activities) while it received data from the simulation model to determine the right hand sides of its constraints. In an iterative way the optimum of the objective constrained by the ecological systems model and the requirements could then be reached. Other approaches that combine results from a systems descriptive model and an optimization procedure (e.g., using the steady state equation belonging to the dynamic model) do not lead to interactive iterative procedures and use less information. Therefore, a type of approach like Lonergan's is preferred.

Comprehensive models (i.e., multidisciplinary, integrated, economic-ecological models) offer good opportunities for dealing with the requirements and demands posed for SD issues. The integration may refer to modules/disciplines, techniques/models and aggregation levels. Some authors propose a combined use of programming, econometric and input-output models (see e.g, Isard 1986). Boyce (1988) has stated that it is time "we recognize the serious limitations of this kind of thinking". He further clarifies that "we should be seeking to integrate our theoretical concepts into more comprehensive model formulations".

Finally, relatively simple **analytical models** can be used, which have the advantage of being easier to handle while the behaviour of the model is tractable. They have the following characteristics:

- a simple description of the processes in the system considered to be most important or relevant for one's purposes; this often boils down to a partial model, or a representation of the global behaviour of the system;
- optimization of one objective;
- a description of an open system focusing on either one open region with openess characterized by exogenous inputs and outputs (or restrictions on inputs and outputs) or a multiregional system characterized by a static, linear or game-theoretic structure.

For SD, the latter class of models can only serve an illustrative purpose, as a global structure is too simple and aggregate or partial, and hence includes limited feedback mechanisms and ecological stress factors. Furthermore, solution algorithms require that the specification of relationships is bound to rigid structures, while objective functions must be one-dimensional.

In order to illustrate the relevance of the RSD concept and of the above remarks on RSD modeling, we will present in the next section the structure and some results of a RSD model for an agricultural area in the Netherlands.

7. <u>A Case study: The Peel Region in The Netherlands.</u>

The Peel area in the south-east of the Netherlands has been selected for a pilot study because of its problematic interactions between the natural resource base and economic activities (see van den Bergh et al., 1988). Two natural fen areas (de Groote Peel and Maria Peel) are situated in an area in which intensive cattle farming and mixed agriculture are the dominant users of the land. The study focuses on the use of forests, natural areas and groundwater. Drainage of the land has been instrumental to the historical development of the region. Extensive drainage still occurs each spring, lowering the water level so that machines can work on the land. During summer, potential (as well as actual) shortfalls in soil moisture are circumvented by irrigation sprinklers; water is derived from groundwater reserves. Recharge of groundwater reserves may be constrained by spring drainage, yet the reserves are used intensively during the summer. There are hence various questions and conflicting issues regarding the 'sustainability' of such practices.

The natural resources in the region are the starting points of our analysis. Economic activities are taken into account insofar as they influence (or are influenced by) these resources. Consequently, the regional boundaries were determined primarily by ecological and geographical criteria, based on the groundwater basin around the Peel-fen reserves (so-called ecohydrological districts; see Braat and van Amstel, 1988).

The **renewable natural resources** central to this study are groundwater, forests and natural vegetation. The issues associated with these may be summarized as follows:

1. high water tables, sandy soil and nutrient-poor conditions have led to the development of unique ecological communities;
2. widespread drainage of the land and multiple use of the groundwater resource (for irrigation as well as municipal supply) has lowered the water tables;
3. agricultural activities, with intensive use of fertilizer and with increasing manure production, are causing nitrate enrichment of the groundwater, with impacts on the remnant vegetation as well as decreasing suitability for human consumption;
4. air pollution is also causing acidification of soils, with impacts on the natural vegetation as well as on forests.

Economic activities which are directly dependent on the groundwater resource include agriculture and municipal water supply. Other activities in the region are timber production, recreation and nature conservation. Especially agriculture is at the present significantly contributing to regional income.

For some activities a further subdivision is useful. For example, timber production is based on two tree species - pines and Douglas fir, both of which are produced in plantations. Agriculture comprises the rearing of livestock (cattle, pigs and poultry), and crop cultivation (for livestock and human consumption); livestock rearing can be intensive (e.g., bioindustry for meat and egg products) and extensive (e.g., dairy and meat).

The spatial distribution of activities in the region also affects their interactions and relationships with resources. For example, groundwater extraction for agriculture is shallow and widespread, whereas that for municipal supply occurs at a small number of sites and involves deeper extraction.

The central focus of this study is the use of the region's natural resource base by the region's economic activities. **Multiple use** is a prominent feature and a source of conflict, since allocation of a scarce resource among users involves trade-offs. For example, economic activities are not the only user of groundwater, while groundwater is also crucial for the regeneration of wetland communities.

The use of the Peel's natural resources as economic goods includes: extraction of groundwater for drinking water; groundwater for irrigation by agriculture; timber in forestry; and soil for growing crops. The use of the Peel's natural resources as services includes: natural areas for recreation and nature conservation; land for disposal of surplus manure; and air, soil and groundwater as deposits of ammonia and nitrate from manure.

The analysis of regional system interactions in this area has resulted in a **dynamic simulation model** programmed in STELLA (Richmond et al., 1987). The model is exploratory in nature. The sub-modules describe groundwater, nitrates, forestry and natural vegetation, agriculture (manure), and regional economic activities. The submodule which describes the economic activity accounts profits over time for each sector, on the basis of developments of quantities, costs, prices and technology. The time paths for quantities (number of products actually sold, or services actually delivered, measured in relevant units for the respective sector) is for most sectors based on changes in production capacity, except for recreation, where demand for recreational activity determines the quantity. The development of the economic system is to a large extent determined by exogenous variables, for which time paths were chosen in each development scenario. The fact that only few interactions between different sectors are modelled has to do with the smallness of the region. Models that include many interactions between sectors (e.g., interindustry supply, or competition on factor and final markets) usually have an economy-wide rather than a regional orientation (cf. Vincent, 1982). The interrelationships between the modules are listed in Figure 1 (see for a more detailed description van den Bergh et al., 1989). The indicator variables chosen for the assessment of RSD are listed in table 1. The indicator for nature conservation value is based on areas of vegetation. Recreational attractiveness is based on economic facilities, natural amenities, and disservices (arising from economic activities).

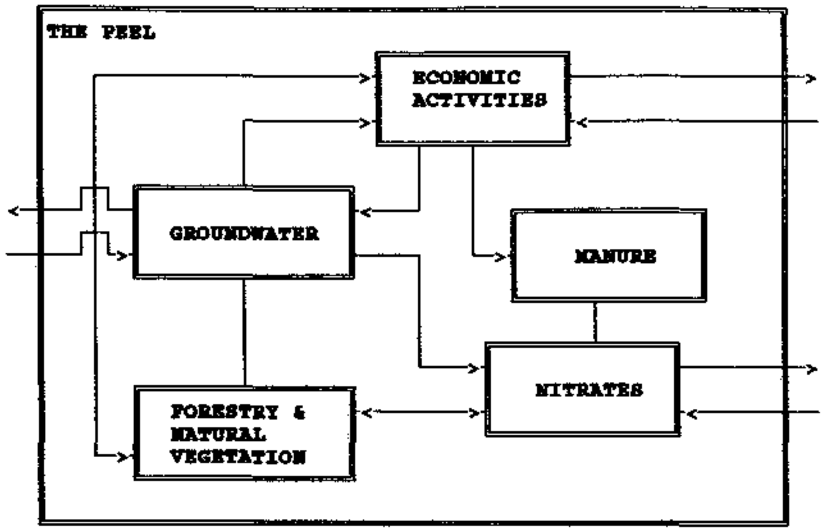

FIGURE 1: Modules and relationships of the Peel model.

1	VALUE ADDED IN THE REGION
2	COSTS OF MEASURES
3	NATURE CONSERVATION VALUE
4	RECREATIONAL ATTRACTIVENESS
5	GROUNDWATER QUALITY WITH RESPECT TO CONCENTRATION OF NITRATES
6	AIR QUALITY WITH RESPECT TO CONCENTRATION OF NITRATES AND AMMONIA IN AIR
7	STOCK OF GROUNDWATER
8	STOCKS OF VEGETATION AND FOREST

TABLE 1. Indicators for RSD in the PEEL area.

Each scenario that is used for a simulation run has effects that will be evaluated regarding their RSD via the indicators listed in table 1. Effects may be compared to standards, and lead to inferences about acception or rejection of the relevance of the scenario used for RSD. The scenarios are determined by choices for both exogenous and management variables. To limit the number of scenarios some plausible scenarios consisting of a set of related changes in variables have been identified. The time-horizon of the scenarios is 50 years with base year 1980/81, while the time resolution is given in years. The model has been run for the scenarios mentioned hereafter. Each scenario description is followed by a concise evaluation of the time paths of indicators.

(1) **Business as usual.**
The assumptions on future developments are the following. The stock of grazing cattle declines from 1980 to 1985 and remains constant during the rest of the simulation period. The stock of feedlot cattle will increase with 10 percent each period of twenty years. Population will increase with 9000 per decade for the period

up to 2000. Trends are extrapolated after that year. Imported nitrogen and sulpuroxides emissions decline; NOx emissions decrease with 30% and SO2 emission with some 45% after 15 years.

The results in figure 2[1] indicate that in this scenario major changes are expected after 15 years. The trend towards grassification of heathland is somewhat delayed. An improvement in air quality (Qair) results, implying that the forest volume of alders (VOLA) increases significantly and the downward trend for douglas firs (VOLD) is stopped. Ammonia and nitrate emissions increase slowly and the concentration of nitrates in deep groundwater (concN-deep) is somewhat higher than under the steady state. After 15 years total value added increases as a result of forest improvement, an increase in recreational revenues resulting from an improved natural environment (reflected in Xn), and an increase in feedlot farming.

(2) **No import of SO2 and NOx.**
This scenario is based on the same assumptions as the business-as-usual scenario with the exception of imported SO2 and NOx emissions. These emissions are set to a zero level after 15 years in order to asses the impact of foreign policies and the possibilities for regional policy. It can also be seen as an assessment of interregional trade-offs.

Compared to the business-as-usual scenario, pH and air quality appear to improve more drastically (Figure 3). It is significant that the trend towards grassification of heathlands would be reversed. Forests improvement, for both douglas and alders, would be strengthened. Value added appears to improve due to the improvement in forestry and recreational value.

(3) **Present environmental policy.**
Based on the business-as-usual scenario and the present government policy to control the utilisation of manure on land, a contemporary environmental policy scenario is created.

The simulation results in figure 4 show that after 15 years a significant decline in ammonia emissions occurs. The downward trends in both alders and wet heathlands is clearly reversed and the share of grassland significantly decreases after some 20 years. The improvements in forestry and natural vegetation, already observed under the business-as-usual scenario, are strengthened. Net present value, apart from the hick-up after 15 years due to a sudden increase in yields not yet counterbalanced by manure disposal costs, eventually rises toward a higher level.

(4) **Present environmental policy plus ammonia scrubbing.**
This scenario is the same as scenario 3, except that now all feedlot stables are provided with biofiltration equipment after 15 years.

Figure 5 shows that, compared to the present environmental policy scenario, the improvement in wet heathland as well as the reduction in grassland is postponed, although an increase in douglas firs is reached sooner. This is caused by an increase in nitrate resulting from biofiltration. Total value added does not alter much in terms of size, but it does so in terms of composition. The costs of biofiltration have a significant impact on the value added in the feedlot industry. This is counterbalanced by the increase in recreational demand and timber production.

1 The symbols in the graphs in figures 2 to 7, concN_deep, N3, pH_soil, Sg_surf, VOLA, VOLD, VOLHW, VOLGR, Sg_deep, Xn, Qair, and addval_tot denote, respectively, the concentration of nitrates in the deep groundwater (kg/ML), the total ammonia release from manure (kg), the soil pH, the volume of surface groundwater (ML), the stock of alders (m3/HA), the stock of Douglas fir (m3/HA), the stock of wet heathland (m3/HA), the stock of grass (m3/HA), the volume of deep groundwater (ML), the nature conservation value (index), the quality of the air (index), and the total value added (Dutch guilders).

(5) **Maximum technical efforts.**
This is the same as scenario 4, except that more stringent technical standards are required. The standards are now based on the uptake of minerals by vegetation. These standards are appoximately twice as low as the governmental standards for 1995. Accordingly, we have reduced the application of manure on land with 50% as compared to scenario 4.

Figure 6 indicates that ammonia emissions are clearly lower after 10 years already. This has a beneficial impact on natural vegetation and forestry where recovery will take place sooner. The costs of this action however have to be born earlier, especially by feedlot farming. Total value added in the region is not significantly affected.

(6) **Land use shifts.**
This is based on the business-as-usual scenario with the exception of the area allocated to arable land. This is reduced with 50% in 1980. The area of land allocated to forestry and natural vegetation increases with approximately 125 %, with the exception of grassland area, whose size is constant.

The volumes of natural vegetation are significantly higher (see Figure 7) than under the first scenario. Also due to less crop irrigation the stock of surface groundwater is higher which positively influences natural vegetation. As can be seen from the figure, initially total value added is some 25% higher but then it drops to remain only slightly above the business-as-usual level.

Further research is required to improve the empirical robustness of the model. Several data would have to be improved in precision. Some equations require more reliable data to enable a realistic specification (e.g., recreational amenity, output from crops as a function of fertiliser and groundwater use). The model might also be validated by means of a historical run as a "backcasting" exercise. Therefore, it is clear that the above results are for the time being mainly illustrative for RSD planning.

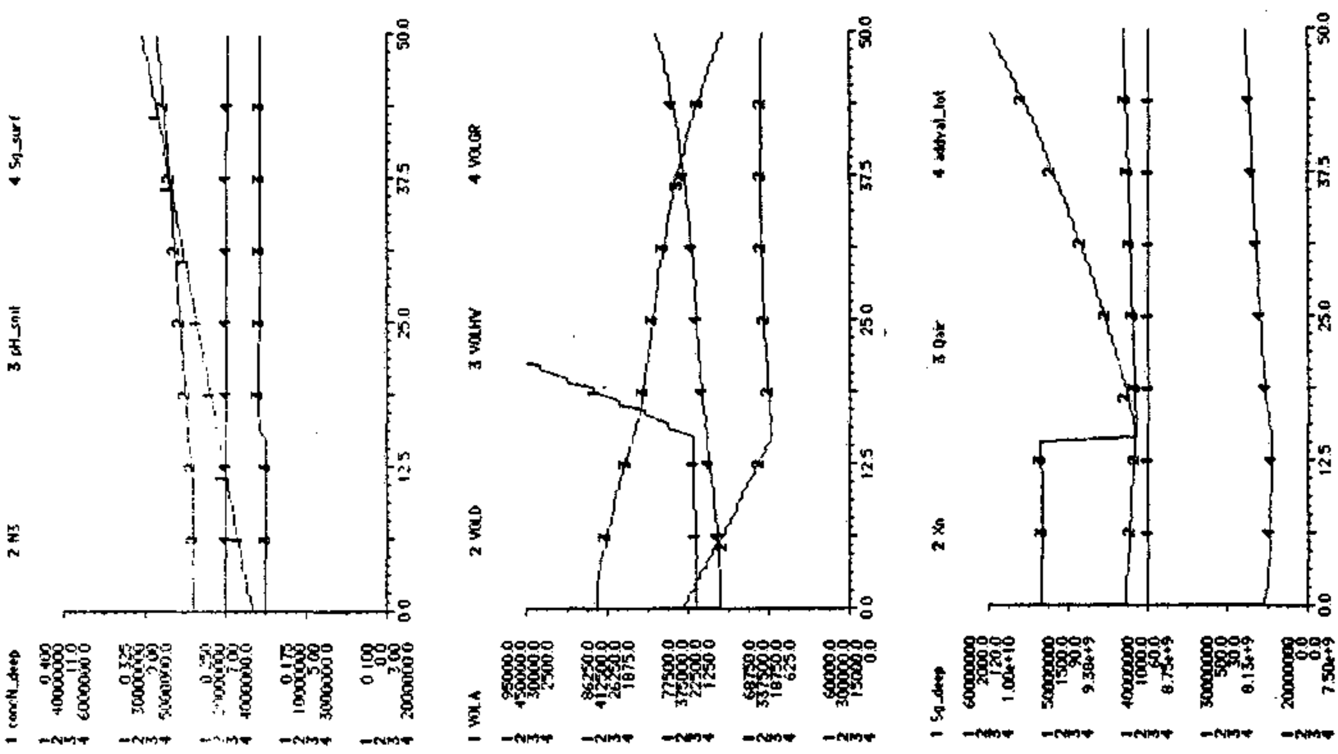

FIGURE 2. Business as usual.

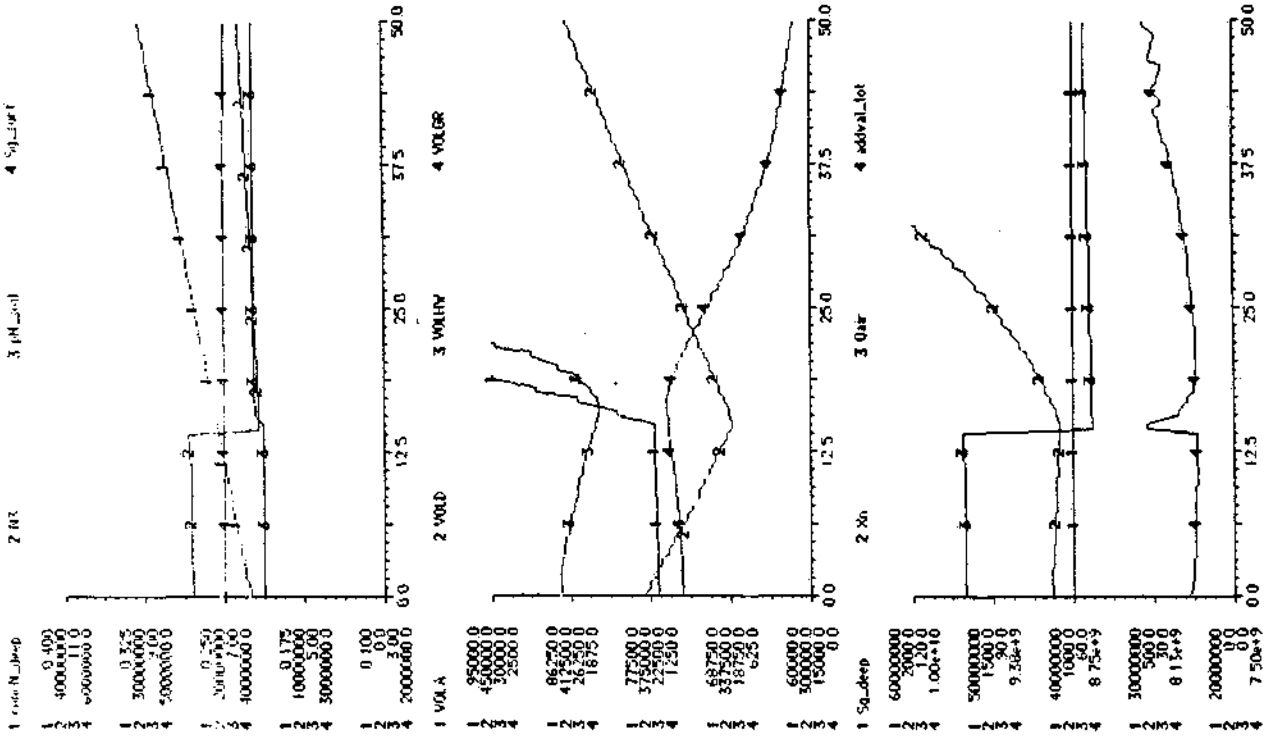

FIGURE 4. Present environmental policy.

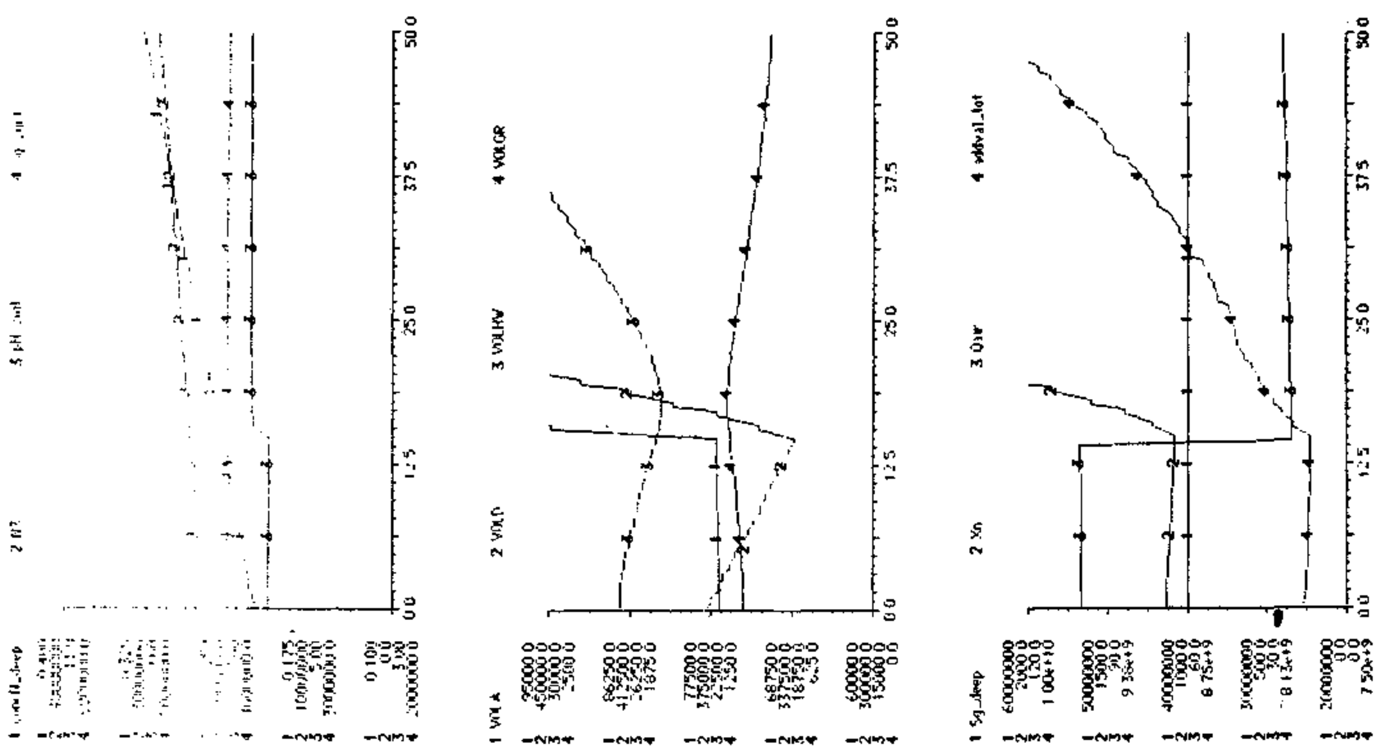

FIGURE 3. No import of SO2 and NOx.

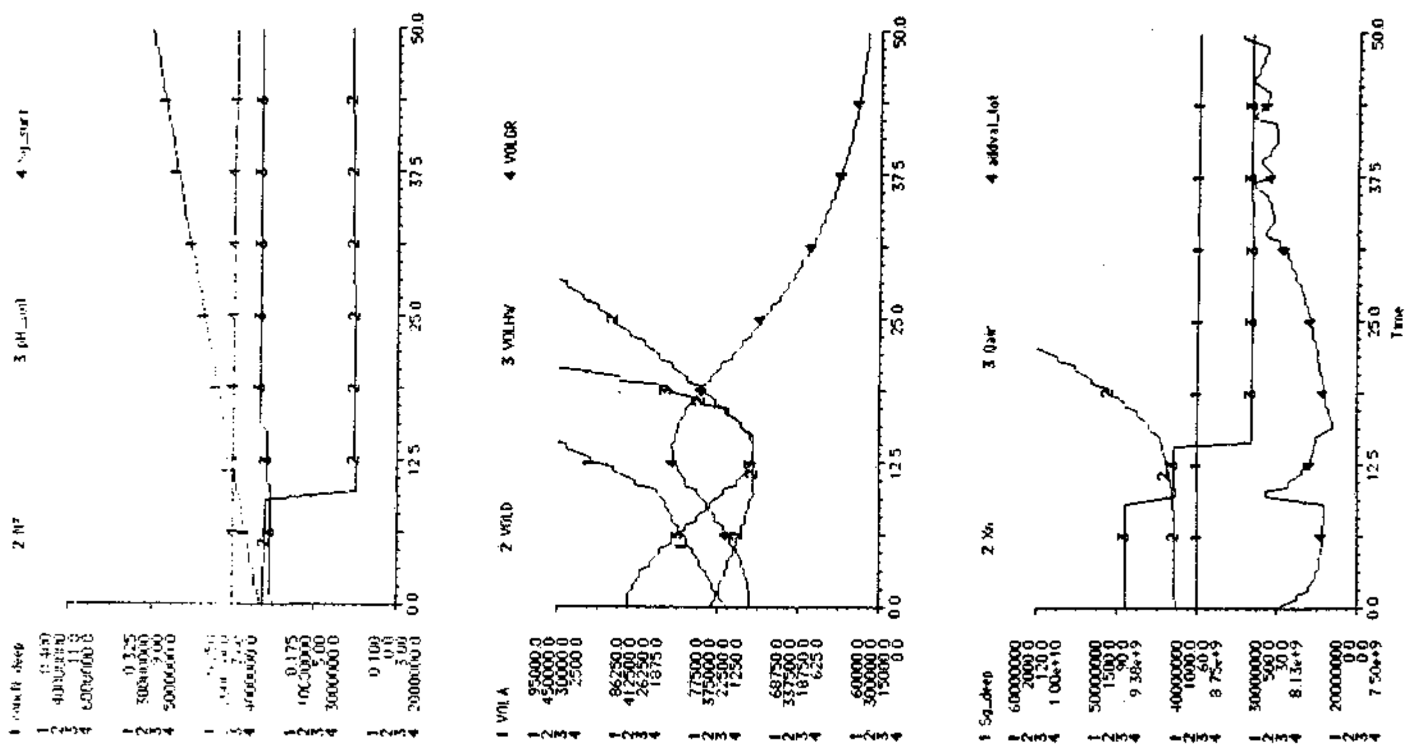

FIGURE 6. Maximum technical efforts.

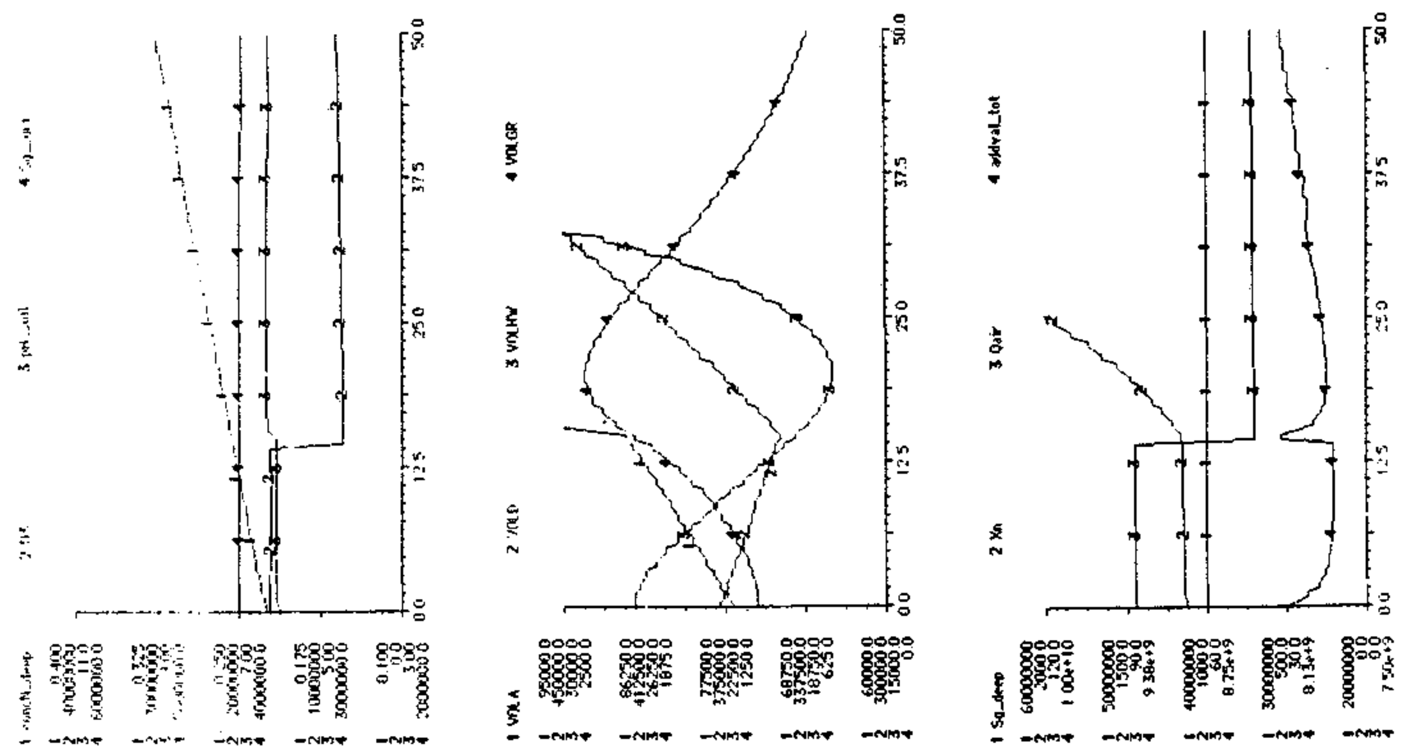

FIGURE 5. Present environmental policy plus ammonia scrubbing.

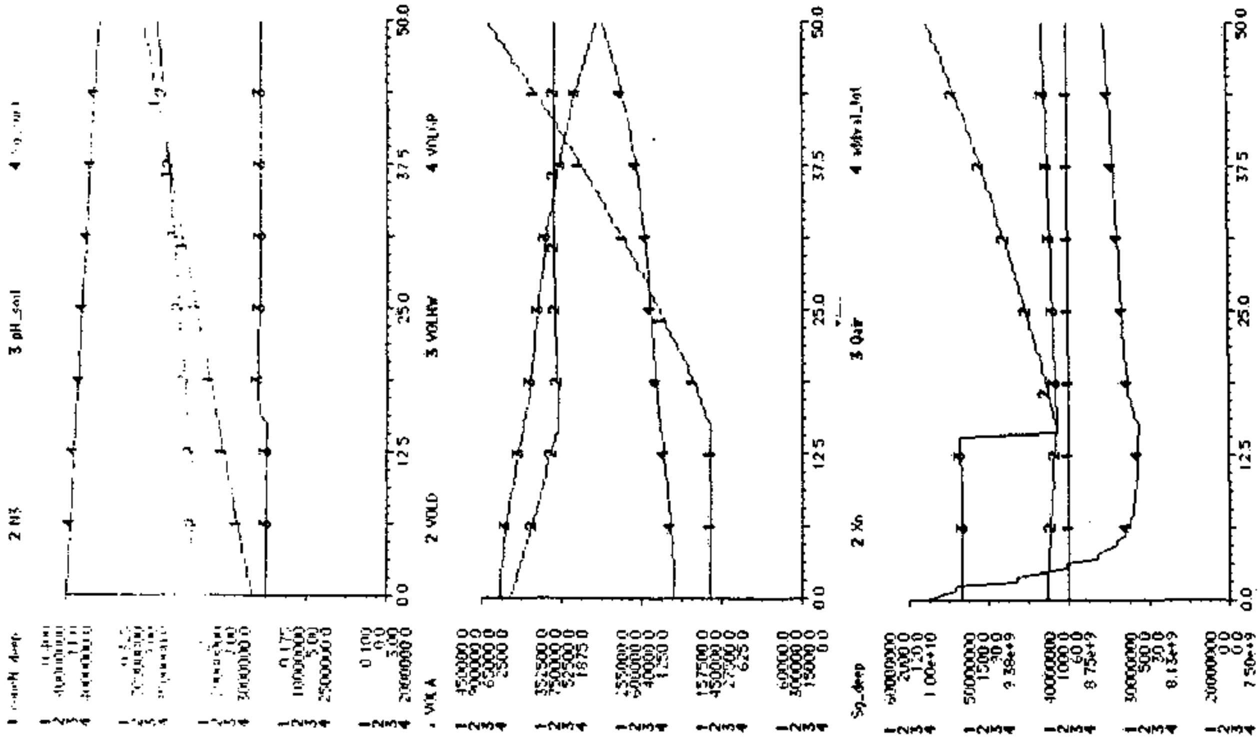

FIGURE 7. Land use shifts.

8. Conclusions.

This paper has focused attention on sustainable development in a regional context. Conceptualizing and analyzing sustainable development is clearly not only important for a global level, but certainly also for a regional level of analysis and policy-making. Various advantages of a regional approach have been spelt out, in relation to regional causes and effects of environmental problems, the global character of economic processes, interregional interactions and the possibility of operationalizing SD on a regional scale. Sustainable use of resources was argued to be an element of RSD. Our first step to RSD analysis was a stock-taking of the internal characteristics of the region, its interactions and relevant external (global) phenomena. In discussing a regional resource base it was argued that the present and potential dependence of regional activities on the resource base as well as the specific characteristics of the resource base should be assessed. With regard to the use of models, the main problems in the context of SD issues have been mentioned. Various caveats of models for SD have been discussed. Such caveats are a consequence of both the regional and integrated economic-ecological character of SD models. Finally, a case study was presented in which some of the general discussions were illustrated, indicators for RSD were mentioned, and a systems descriptive model was developed. Simulation results were presented for scenarios including very different, although realistic future options with regard to continuation of present level of cattle-breeding, environmental policy, technologically feasible emission levels, and land use shifts.

References.

Amstel, J. van, and Braat, L.C. (1989), Verdroging, Institute for Environmental Studies, Free University, Amsterdam, in Dutch

Archibugi, F. and P. Nijkamp (eds) (1989), Economy and ecology: towards sustainable development, Kluwer Nijhoff, Dordrecht

Baumol, W. and J. Benhabib (1989), "Chaos: Significance, mechanism, and economic applications", J. Econ. Perspectives 3, 77-106

Bergh, J.C.J.M. van den, L.C. Braat, A.J. Gilbert, D.E. James, G. Klaassen, F.J. Soeteman and I. Steetskamp (1988), Sustainable use of natural resources and economic development in the Peel., Interim report SPIDER research program, Institute for Environmental Studies and Department of Regional Economics, Free University, Amsterdam

Brouwer, F. (1987), Integrated environmental modelling: Design and Tools, Kluwer Academic Publishers, Dordrecht

Brouwer, F. and P. Nijkamp (1988), " Design and structure analysis of integrated environmental planning models", Eur. Rev. of Agric. Ec. 15, 1-38

Brown, B.J., et al (1987), Global sustainability: toward definition, Environmental Management 11, 713-719

Hafkamp, W.A. (1984), Triple layer model: a national-regional economic-environmental model for the Netherlands, North-Holland, Amsterdam

Holling, C.S. (ed.) (1978), Adaptive Environmental Assessment and Management, Wiley, New York

Isard, W. (1986), "Reflections on the relevance of integrated multiregion models", Reg. Sc. Urb. Ec. 16, 165-180

Law, A.M. and W.S. Kelton (1982), Simulation modeling and analysis, McGraw-Hill, New York

Lonergan, S.C. (1981), "A methodological framework for resolving ecological/economic problems", Papers of the Reg. Sc. Ass. 3, 117-134

Miernyk, W.H. (1982), Regional analysis and regional policy, Oelgeschlager, Gunn and Hain, Cambridge Massachusetts

Nijkamp, P., and A. Reggiani (1990), "Logit models and chaotic behaviour", Environment and Planning A (forthcoming)

Opschoor, J.B. (1987), Duurzaamheid en verandering: Over ecologische inpasbaarheid van economische ontwikkelingen (Sustainability and change), Inaugural Address, Free University, Amsterdam (in Dutch)

Pearce, D.W., E. Barbier and A. Markandya (1988), Sustainable development and cost benefit analysis, Canadian Environmental Assessment Research Council Workshop on Integrating Economic and Environmental Assessment, Vancouver

Richmond, B. et al., (1987), STELLA userguide, Dartmouth College, Lyme, New Hampshire

Siebert, H. (ed.) (1984), The resource sector in an open economy, Springer-Verlag

The World Commission on Environment and Development (WCED) (1987), Our Common Future, Oxford University Press

Tolba, M.K. (1987), Sustainable development: Constraints and opportunities, Butterworths, London

Vincent, D.P. (1982), "The ORANI approach to quantitative modelling of the Australian agricultural sector", Eur. Rev. of Agr. Ec. 9, 415-442

Wilen, J.E. (1985), "Bioeconomics of renewable resource use", in A.V. Kneese and J.L. Sweeney, Handbook of natural resource and energy economics, vol 1, North-Holland